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To Mr. J.V. Doyle
Manager
Civil Works Department
Thermal and Hydraulic Generation Division

Attn: Mr. G.F. Smith

# MOUNTAIN CHUTE GS
# NEW GEOTECHNICAL INSTRUMENTATION

C.B.H. Cragg

Installation of a normal pendulum, an inverse pendulum and alignment survey monuments at the Mountain Chute main dam are described. Initial pendulum readings are also presented.

## 1.0 INTRODUCTION

A review of the Mountain Chute GS instrumentation /1/ recommended that new devices be installed in the main dam to monitor deformation and that existing observation wells be repaired. This report documents the installation of the survey monuments, normal pendulum and inverse pendulum recommended for the deformation monitoring. Initial readings of the pendulums are also included.

## 2.0 SITE DESCRIPTION

Mountain Chute GS main dam is a concrete gravity structure with a crest length of 1400 feet and a maximum height of 172 feet. While the crest of this structure is generally straight, a small portion of the dam, near the right abutment, angles downstream (see Figure 1). The structure is founded on rock. Rock outcrops rise above the dam crest at the left abutment but soil covers the rock on the right abutment. Construction of this project was completed in 1967.

## 3.0 INSTRUMENTS INSTALLED

The purpose of the new instrumentation is to provide information on structural movements in both the vertical and horizontal directions. The new instruments installed in the dam include:

(a) 1 normal pendulum in the headworks stairwell at chainage 19+25 approximately.


| job | file | date | report no. |
|---|---|---|---|
| 43-146-575 | 843.12 | October 7, 1987 | 87-25-K |

(b) 1 inverse pendulum in the powerhouse to inspection tunnel access tunnel, directly below the stairwell to the headworks, at chainage 19+30 approximately.

(c) 6 survey brass caps in the dam deck.

(d) 1 concrete bench mark near the right abutment.

Figure 1 shows the plan location of these instruments. A cross section of the pendulum installations is given in Figure 2.

## 4.0 NORMAL PENDULUM

The normal pendulum is located on the east wall of the headworks stairwell (approximate chainage 19+25). Due to a horizontal change in stairwell location at mid-height, this pendulum only extends from deck level (elevation 820) to the offset level (elevation 767).

An initial set of readings of the normal pendulum, including microlevel readings was performed. (The microlevel is a portable tiltmeter.) The readings will be used to monitor deformations of the main dam. The microlevel readings will show if the reading table has been disturbed. The initial readings of the normal pendulum and the microlevel readings are included in this report as Appendix I.

## 5.0 INVERSE PENDULUM

The inverse pendulum was installed adjacent to the normal pendulum in the headworks stairwell. The inverse pendulum hole was drilled NQ size from the base of the stairwell to a depth of 82 feet 6 inches. Drilling procedures that were developed by Hydro Quebec/2/ were used in the installation. Figure 3 shows the location and amount of correction that was required in drilling the pendulum hole. The material encountered by the drill consisted of 20 feet 9 inches of concrete followed by 61 feet 9 inches of crystalline limestone containing a rubble zone. The drill core was examined and logged and is included in this report as Figure 4. Core samples revealed approximately 2 feet of weathered and heavily fractured crystalline limestone immediately below the dam followed by a thin (1 inch) weathered rubble zone which does not appeare sheared. The remainder of the core consisted of white crystalline limestone which in one location showed some evidence of past fracturing. No water was lost during drilling into bedrock.

A protective casing has been installed by the regional staff, where the pendulum wire extends through pedestrian traffic areas, to prevent damage and reduce disturbance to the pendulum.

An initial set of readings of the inverse pendulum, including autocentring device/3/ and microlevel readings, were performed. These readings will be used to identify if and where deformations of the main dam have occurred. The microlevel readings will identify if the reading table has been disturbed. The initial readings of the inverse pendulum are included in

this report as Appendix I. The autocentring device readings are included in this report as Appendix II.

## 6.0 SURVEY MONUMENTS

Six survey monuments, consisting of 2.5 inch diameter brass caps engraved "CIVIL WORKS, 1986", were installed across the top of the dam at 15+29.5, 17+29.5, 19+29.5, 21+15.5, 23+15.5 and 25+15.5. One brass cap, at 19+29.5, was installed on the same concrete block near the top of the normal pendulum. Since these brass caps will be used for elevation and alignment monitoring they have been established on line using two existing brass caps located above the spillway (25+10) and above the penstock (18+89.5) to establish the survey line.

A new benchmark was established, on line with the new brass caps, adjacent to the right abutment of the dam (Figure 1 and Figure 5). The benchmark was constructed by excavating 5 feet to bedrock, leveling the base, drilling eight 7/8 inch diameter holes and grouting eight 6 foot long and 5/8 inch diameter rebar into the drill holes. The rebar was then tied, a form constructed, concrete poured and the brass cap installed on line. The excavation around this concrete benchmark was backfilled with the excavated material.

## 7.0 DISCUSSIONS

The installation of inverse and normal pendulums was completed at Mountain Chute GS and an initial set of readings was obtained. In addition, 6 brass caps have been installed across the top of the dam.

An annual inspection of the apparatus will be required to ensure that these instruments remain in good operating condition.

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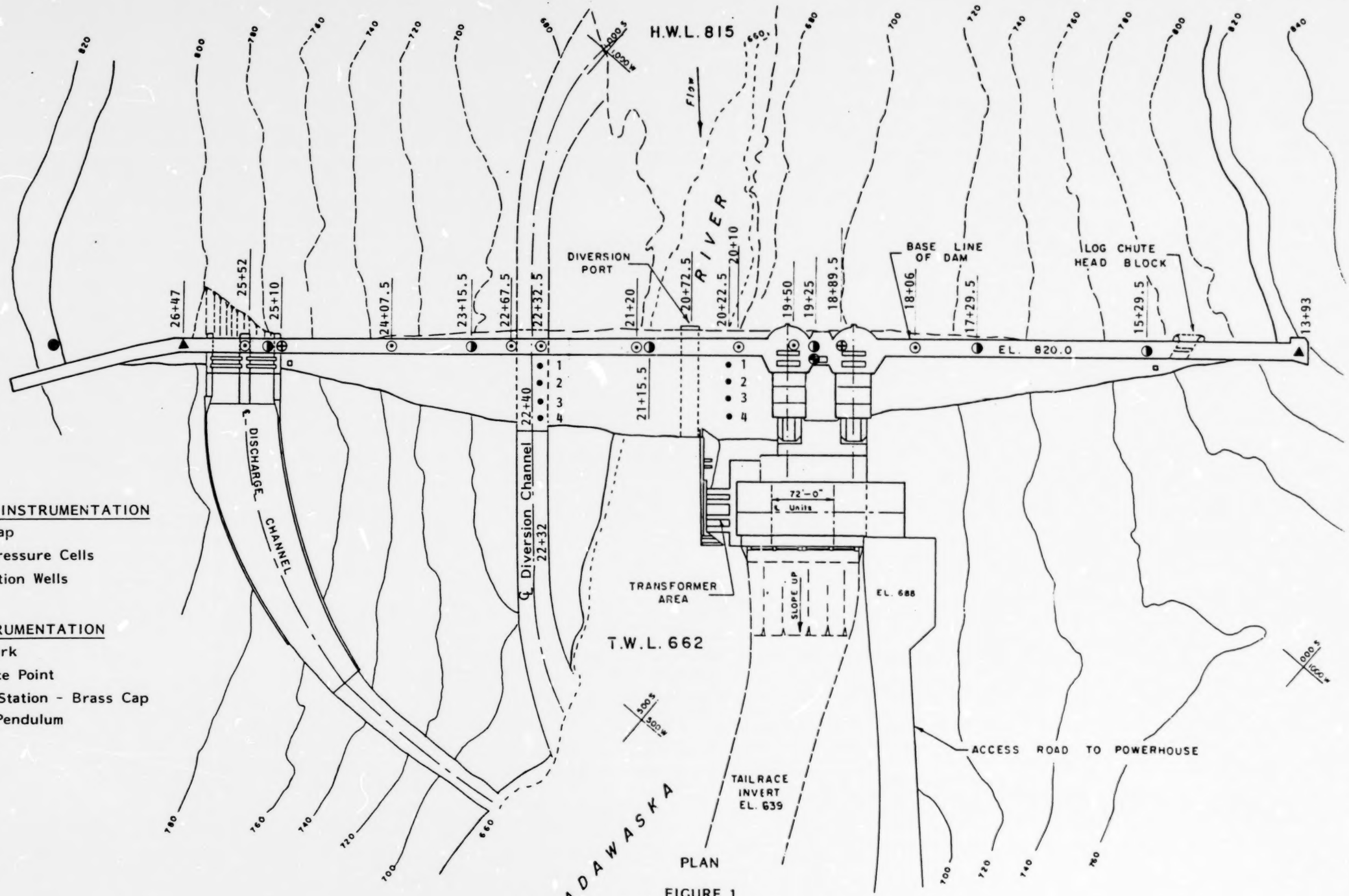
CBHC:LM

REFERENCES

1. C.B.H. Cragg. "Mountain Chute GS - Proposed New Instrumentation - 1986". Research Division Report No S86-24-K, 1986.

2. L. Dubreuil and R. Hamelin. "Vertical Drilling of Inverse Pendulum Holes". Second Canadian Symposium on Mining, Surveying and Rock Deformation Measurements, Kingston, Ontario, 1974.

3. R. Hamelin and B. Boyer. "Instruments for Monitoring the Profile of Vertical and Inclined Holes". 35th Canadian Geotechnical Conference, Montreal, 1982.




EXISTING INSTRUMENTATION

- ⊕ Brass Cap
- • Uplift Pressure Cells
- ⊙ Observation Wells

NEW INSTRUMENTATION

- ● Benchmark
- ▲ Reference Point
- ◑ Survey Station - Brass Cap
- ◓ Normal Pendulum

FIGURE 1

MOUNTAIN CHUTE G.S.
NEW AND EXISTING INSTRUMENT LOCATIONS

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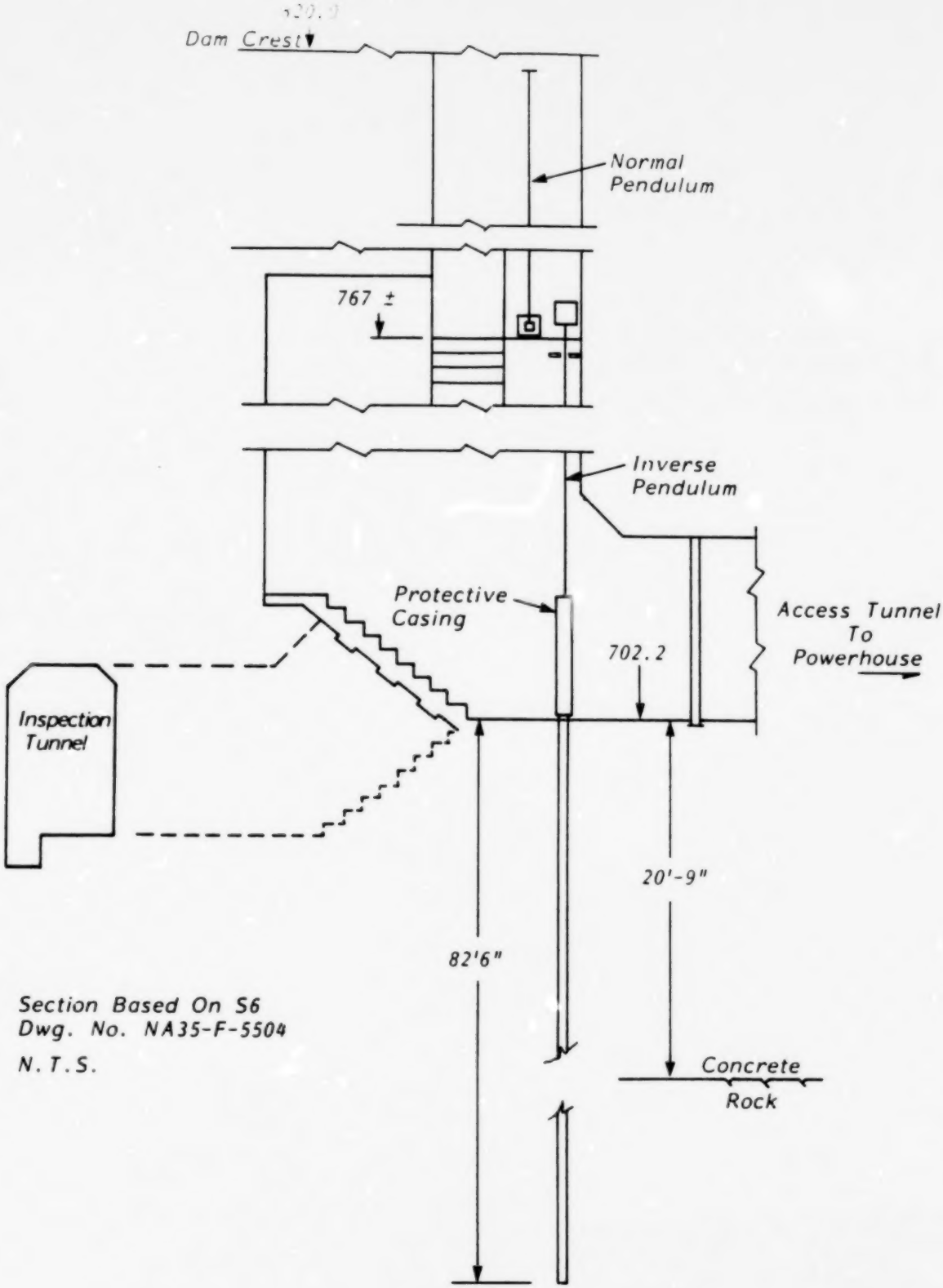


FIGURE 2

MOUNTAIN CHUTE GS PENDULUMS IN POWERHOUSE TO HEADWORKS STAIRWELL

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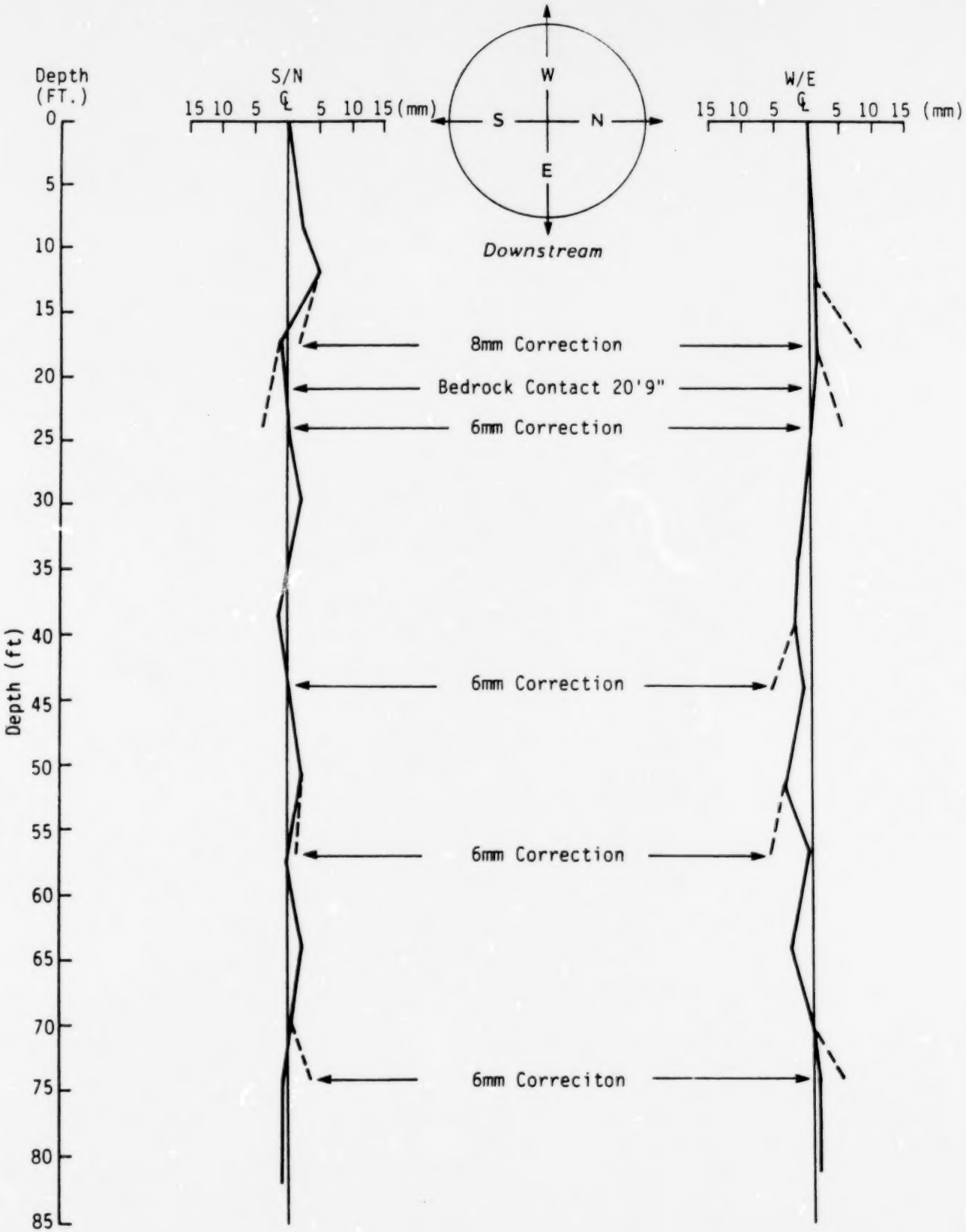



FIGURE 3

MOUNTAIN CHUTE GS
INVERSE PENDULUM BOREHOLE PROFILE

173755-RD

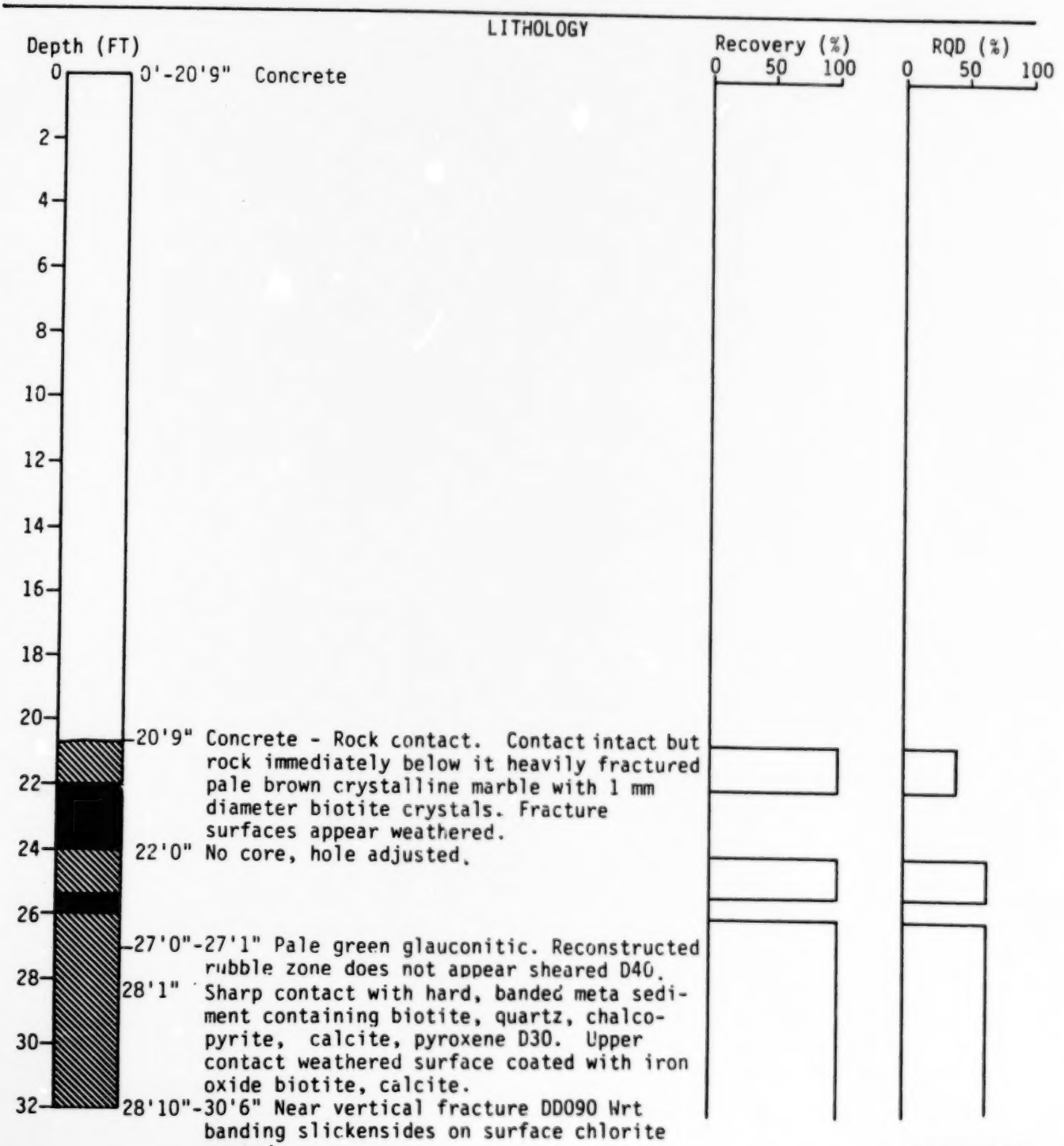
FIGURE 4

BEDROCK LITHOLOGY

Project: Mountain Chute
Borehole No.: None

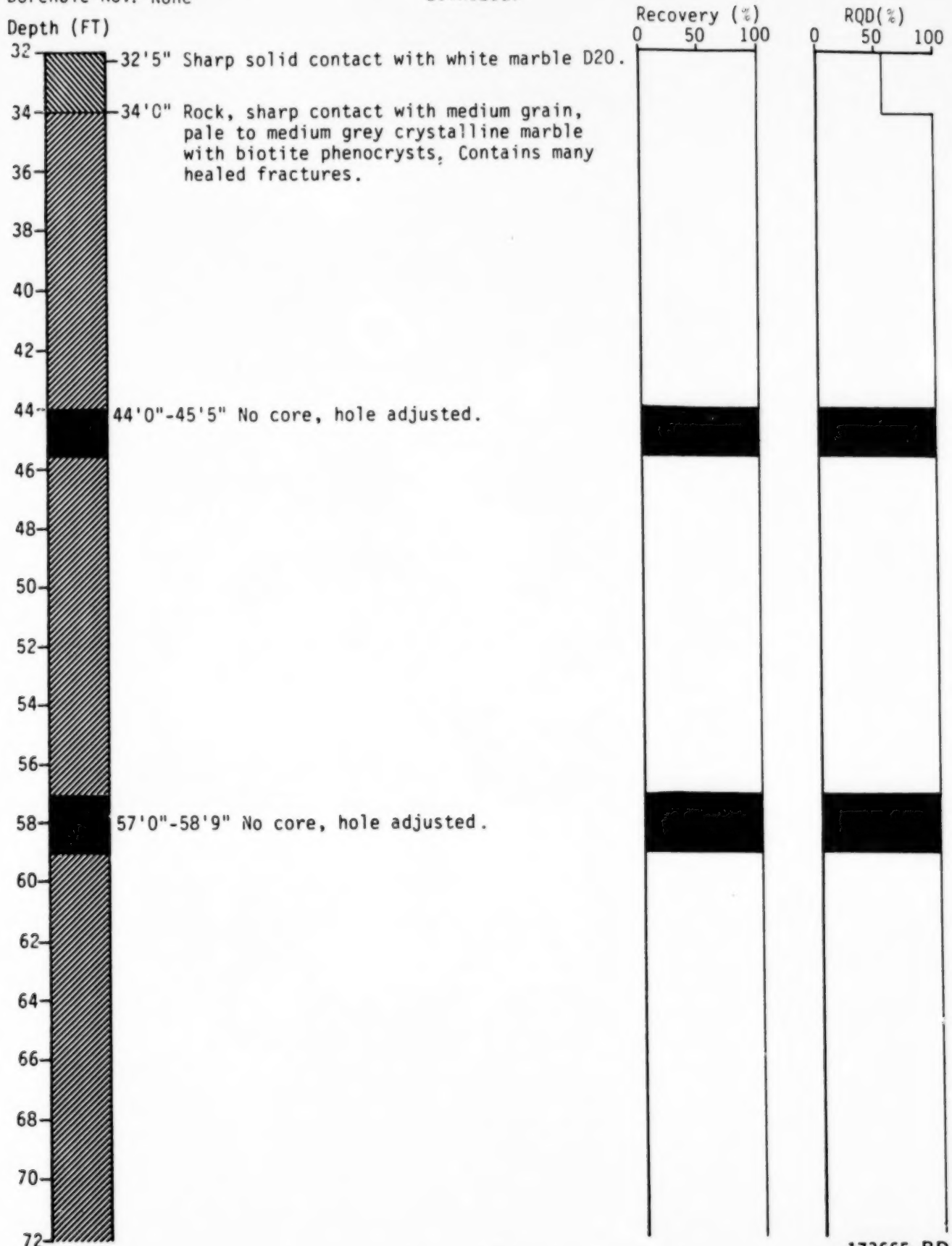
Location: Inverse Pendulum
Chainage:
Collar Elev.:
Dip:
Azimuth:





Project: Mountain Chute
Borehole No.: None

LITHOLOGY



Project: Mountain Chute
Borehole No.:None

LITHOLOGY

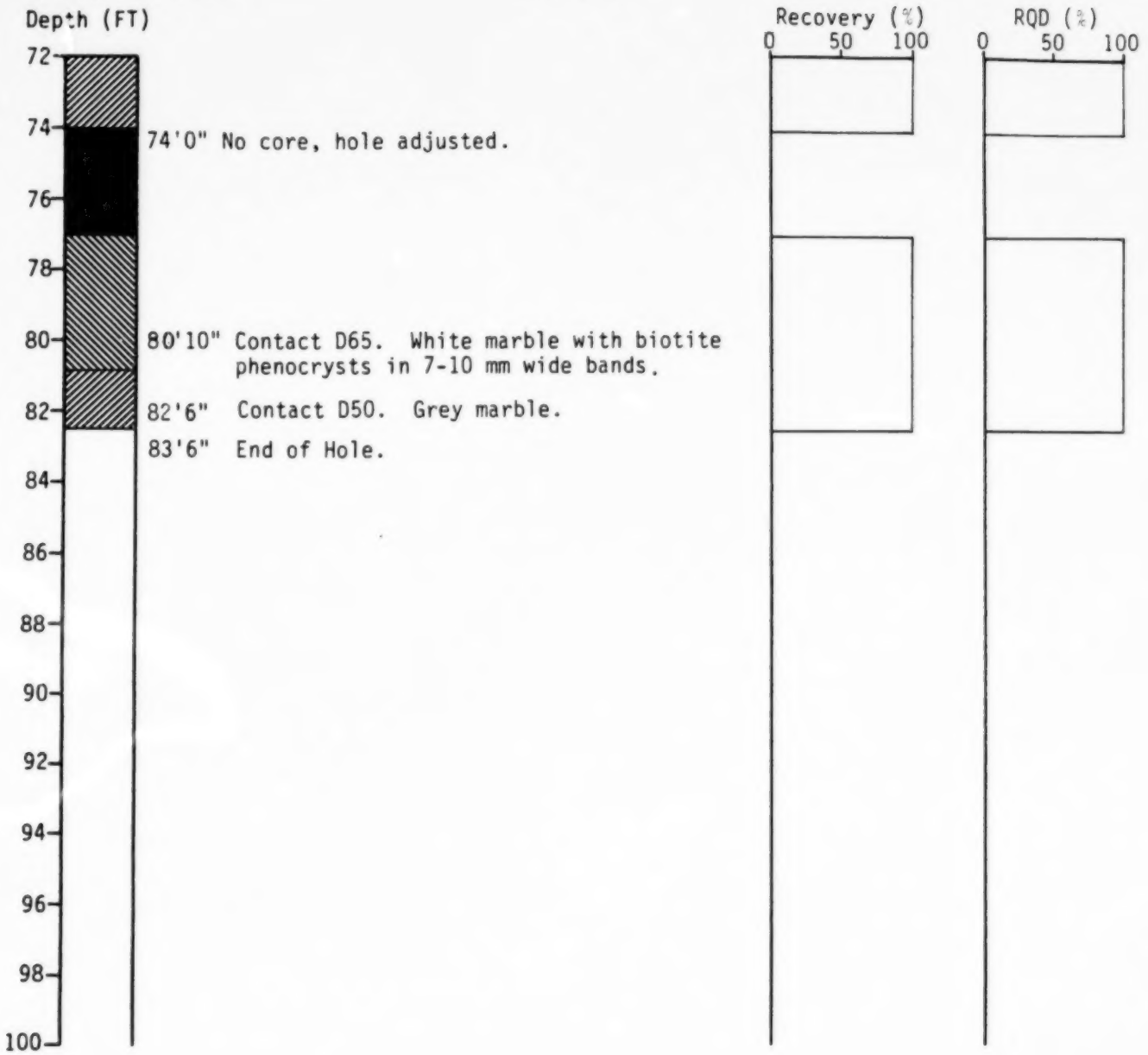


FIGURE 5

MOUNTAIN CHUTE GS
NEW BENCHMARK OFF RIGHT SIDE OF MAIN DAM

## GEOLOGIC KEY

*Limestone*

*Sandy Limestone*

*Shaley Limestone*

*Sandy, Shaley Llmestone*

*Dolostone*

*Sandstone*

*Metamophosed Sandstone*

*Marble*

*Banded Grey Marble*

*No Core*

*D* — *Dip of a Feature*

*DD* — *Directional of Dip of a Feature with Respect to the Direction in which the Pricipal Geologic Feature such as Bedding of Metamorphic Banding*

## APPENDIX I

## Initial Readings for Normal and Inverse Pendulums

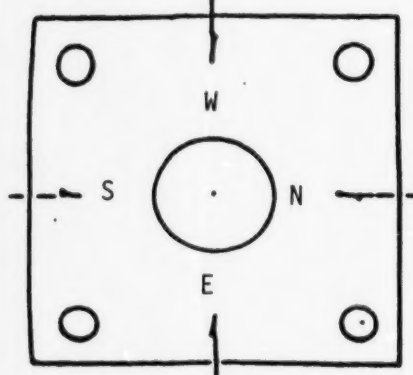
## APPENDIX I

MOUNTAIN CHUTE GS

DATE: April 7/87

READ BY: A. Morton & D. Fraser

### Inverted Pendulum




original reading 1.469
current reading 1
2
3

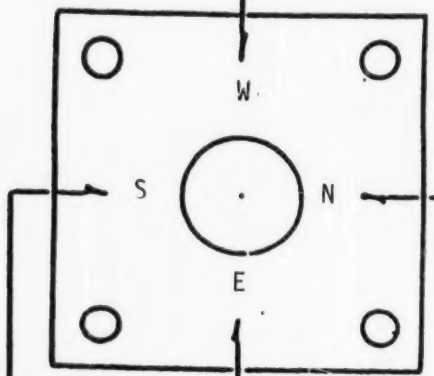
original reading 1.642
current reading 1
2
3

original reading 1.611
current reading 1
2
3

original reading 1.457
current reading 1
2
3

MICRO LEVELS E-W (FS) + 0.81°
N-S (FW) - 0.09°

### Normal Pendulum




original reading 1.549
current reading 1
2
3

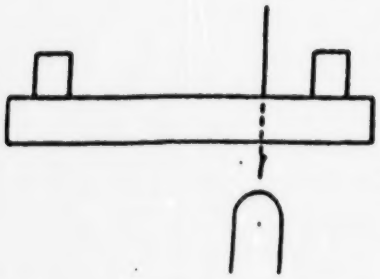
original reading 1.548
current reading 1
2
3

original reading 1.531
current reading 1
2
3

original reading 1.529
current reading 1
2
3

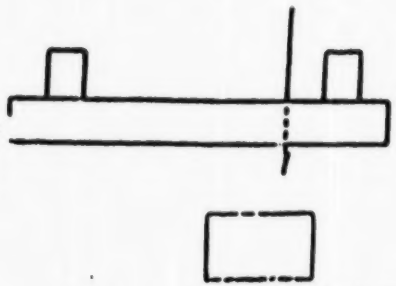
MICRO LEVELS E-W (FS) -0.10°
N-S (FW) -0.26°

Invar/Pin



original reading 1.236
current reading 1
2
3

Invar/Block



original reading 1.637
current reading 1
2
3

| INVERSE | READING CHECK | NORMAL |
|---|---|---|
| 3.075 | = sum of N & S should = | 3.080 |
| 3.075 | = sum of E & W should = | 3.082 |

READINGS ARE IN INCHES

## APPENDIX II

## Inverse Pendulums - Initial Autocentering Device Readings

Inverted Pendulum
Datum Readings

Page ___ of ___

DATE: April 7/87.

TEMP.: ____

Observer AM + DF

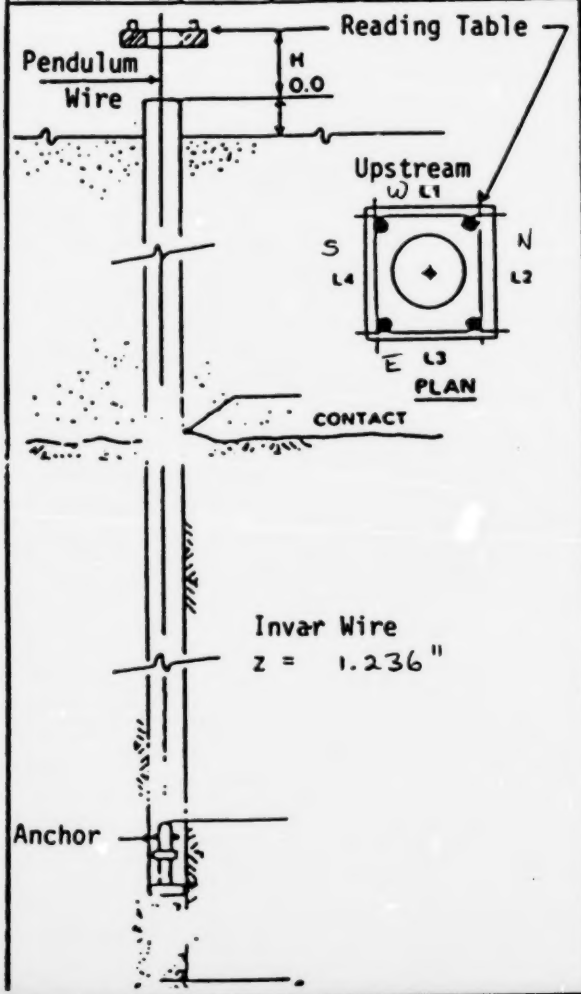
Marker ____

Chainage 19 + 30

Elevation ____

PROJECT: Mountain Chute GS

| Depth (ft) | Axis | Rdg No | Reading Inches | Position | Actual Position | Original Position | Displacement |
|---|---|---|---|---|---|---|---|
| Reading Table H = ____ | X | L2 | 1.642 | -0.093 | (Px) -0.093 | ____ | ____ |
| | | L4 | 1.457 | | | | |
| | | L2 | | ____ | | | |
| | | L4 | | | | | |
| | Y | L1 | 1.469 | +0.071 | (Py) +0.071 | ____ | ____ |
| | | L3 | 1.611 | | | | |
| | | L1 | | ____ | | | |
| | | L3 | | | | | |




Position of centre of the reading table relative to the pendulum anchor

$x = \frac{L4 - L2}{2}$ $y = \frac{L3 - L1}{2}$

Auto centering device
Position of the wire, at various depths relative to the pendulum anchor

$x = \frac{L2 - L4}{2} + Px$

$y = \frac{L1 - L3}{2} + Py$

Table Constant x = 3.075"

y = 3.075"

Wire Diameter 0.050"

MICRO LEVEL DATUMS

E-W (FS) + 0.81°

N-S (FW) - 0.09°

DATE: April 7/87

TEMP.:

INVERSE PENDULUM
AUTO-CENTERING DEVICE

1 of 4

AM + DF

19+30

Mountain Chute GS

PLOT:

| DEPTH (ft) | AXIS | | READING (inches) | POSITION | ACTUAL POSITION | ORIGINAL POSITION | DISPLACEMENT |
|---|---|---|---|---|---|---|---|
| 4 | X | L2 ↓ | 1.544 | -0.086 | -0.086 | | |
| | | L4 ↓ | 1.530 | | | | |
| | | L2 ↑ | | | | | |
| | | L4 ↑ | | | | | |
| | Y | L1 ↓ | 1.399 | -0.069 | -0.069 | | |
| | | L3 ↓ | 1.679 | | | | |
| | | L1 ↑ | | | | | |
| | | L3 ↑ | | | | | |
| 9 | X | L2 ↓ | 1.513 | -0.123 | -0.123 | | |
| | | L4 ↓ | 1.572 | | | | |
| | | L2 ↑ | | | | | |
| | | L4 ↑ | | | | | |
| | Y | L1 ↓ | 1.404 | -0.066 | -0.066 | | |
| | | L3 ↓ | 1.678 | | | | |
| | | L1 ↑ | | | | | |
| | | L3 ↑ | | | | | |
| 14 | X | L2 ↓ | 1.549 | -0.079 | -0.079 | | |
| | | L4 ↓ | 1.520 | | | | |
| | | L2 ↑ | | | | | |
| | | L4 ↑ | | | | | |
| | Y | L1 ↓ | 1.452 | -0.012 | -0.012 | | |
| | | L3 ↓ | 1.618 | | | | |
| | | L1 ↑ | | | | | |
| | | L3 ↑ | | | | | |
| 19 | X | L2 ↓ | 1.613 | -0.019 | -0.019 | | |
| | | L4 ↓ | 1.465 | | | | |
| | | L2 ↑ | | | | | |
| | | L4 ↑ | | | | | |
| | Y | L1 ↓ | 1.492 | +0.027 | +0.027 | | |
| | | L3 ↓ | 1.579 | | | | |
| | | L1 ↑ | | | | | |
| | | L3 ↑ | | | | | |

$P_x$: -0.093

$P_y$ +0.071



87-25

Rev. 12.77

DATE: April 7/17

TEMP.:

INVERSE PENDULUM
AUTO-CENTERING DEVICE

2 of 4

AM+DF

19+30

Mountain Chute GS PLOT:

| DEPTH (ft) | AXIS | | READING (inches) | POSITION | ACTUAL POSITION | ORIGINAL POSITION | DISPLACEMENT |
|---|---|---|---|---|---|---|---|
| 24 | X | L2 ↓ | 1.672 | +0.046 | +0.046 | | |
| | | L4 ↓ | 1.395 | | | | |
| | | L2 ↑ | | | | | |
| | | L4 ↑ | | | | | |
| | Y | L1 ↓ | 1.463 | -0.004 | -0.004 | | |
| | | L3 ↓ | 1.612 | | | | |
| | | L1 ↑ | | | | | |
| | | L3 ↑ | | | | | |
| 29 | X | L2 ↓ | 1.711 | +0.083 | +0.083 | | |
| | | L4 ↓ | 1.359 | | | | |
| | | L2 ↑ | | | | | |
| | | L4 ↑ | | | | | |
| | Y | L1 ↓ | 1.365 | -0.102 | -0.102 | | |
| | | L3 ↓ | 1.711 | | | | |
| | | L1 ↑ | | | | | |
| | | L3 ↑ | | | | | |
| 34 | X | L2 ↓ | 1.740 | +0.108 | +0.108 | | |
| | | L4 ↓ | 1.338 | | | | |
| | | L2 ↑ | | | | | |
| | | L4 ↑ | | | | | |
| | Y | L1 ↓ | 1.302 | -0.166 | -0.166 | | |
| | | L3 ↓ | 1.776 | | | | |
| | | L1 ↑ | | | | | |
| | | L3 ↑ | | | | | |
| 39 | X | L2 ↓ | 1.753 | +0.126 | +0.126 | | |
| | | L4 ↓ | 1.315 | | | | |
| | | L2 ↑ | | | | | |
| | | L4 ↑ | | | | | |
| | Y | L1 ↓ | 1.226 | -0.238 | -0.238 | | |
| | | L3 ↓ | 1.844 | | | | |
| | | L1 ↑ | | | | | |
| | | L3 ↑ | | | | | |

Pa: ____

( ____

DATE: April 7/17

TEMP.:

INVERSE PENDULUM
AUTO-CENTERING DEVICE

3 of 4

AM+DF

19+30

Mountain Chute GS PLOT:

| DEPTH (ft) | AXIS | | READING (inches) | POSITION | ACTUAL POSITION | ORIGINAL POSITION | DISPLACEMENT |
|---|---|---|---|---|---|---|---|
| 44 | X | L2 ↓ | 1.727 | +0.097 | +0.097 | | |
| | | L4 ↓ | 1.348 | | | | |
| | | L2 ↑ | | | | | |
| | | L4 ↑ | | | | | |
| | Y | L1 ↓ | 1.190 | -0.277 | -0.277 | | |
| | | L3 ↓ | 1.885 | | | | |
| | | L1 ↑ | | | | | |
| | | L3 ↑ | | | | | |
| 49 | X | L2 ↓ | 1.667 | +0.039 | +0.039 | | |
| | | L4 ↓ | 1.403 | | | | |
| | | L2 ↑ | | | | | |
| | | L4 ↑ | | | | | |
| | Y | L1 ↓ | 1.187 | -0.281 | -0.281 | | |
| | | L3 ↓ | 1.896 | | | | |
| | | L1 ↑ | | | | | |
| | | L3 ↑ | | | | | |
| 54 | X | L2 ↓ | 1.602 | -0.030 | -0.030 | | |
| | | L4 ↓ | 1.476 | | | | |
| | | L2 ↑ | | | | | |
| | | L4 ↑ | | | | | |
| | Y | L1 ↓ | 1.201 | -0.271 | -0.271 | | |
| | | L3 ↓ | 1.884 | | | | |
| | | L1 ↑ | | | | | |
| | | L3 ↑ | | | | | |
| 59 | X | L2 ↓ | 1.530 | -0.101 | -0.101 | | |
| | | L4 ↓ | 1.545 | | | | |
| | | L2 ↑ | | | | | |
| | | L4 ↑ | | | | | |
| | Y | L1 ↓ | 1.278 | -0.194 | -0.194 | | |
| | | L3 ↓ | 1.807 | | | | |
| | | L1 ↑ | | | | | |
| | | L3 ↑ | | | | | |

DATE: April 7/57

TEMP.: 

INVERSE PENDULUM
AUTO-CENTERING DEVICE

4 of 4

AM + DF

19-30

Mountain Chute GS PLOT: 

| DEPTH (ft) | AXIS | | READING (inches) | POSITION | ACTUAL POSITION | ORIGINAL POSITION | DISPLACEMENT |
|---|---|---|---|---|---|---|---|
| 64 | X | L2 ↓ | 1.493 | -0.132 | -0.132 | | |
| | | L4 ↓ | 1.570 | | | | |
| | | L2 ↑ | | | | | |
| | | L4 ↑ | | | | | |
| | Y | L1 ↓ | 1.332 | -0.135 | -0.135 | | |
| | | L3 ↓ | 1.744 | | | | |
| | | L1 ↑ | | | | | |
| | | L3 ↑ | | | | | |
| 61 | X | L2 ↓ | 1.481 | -0.146 | -0.146 | | |
| | | L4 ↓ | 1.586 | | | | |
| | | L2 ↑ | | | | | |
| | | L4 ↑ | | | | | |
| | Y | L1 ↓ | 1.389 | -0.082 | -0.082 | | |
| | | L3 ↓ | 1.695 | | | | |
| | | L1 ↑ | | | | | |
| | | L3 ↑ | | | | | |
| 74 | X | L2 ↓ | 1.542 | -0.095 | -0.095 | | |
| | | L4 ↓ | 1.546 | | | | |
| | | L2 ↑ | | | | | |
| | | L4 ↑ | | | | | |
| | Y | L1 ↓ | 1.419 | -0.052 | -0.052 | | |
| | | L3 ↓ | 1.665 | | | | |
| | | L1 ↑ | | | | | |
| | | L3 ↑ | | | | | |
| | X | L2 ↓ | | | | | |
| | | L4 ↓ | | | | | |
| | | L2 ↑ | | | | | |
| | | L4 ↑ | | | | | |
| | Y | L1 ↓ | | | | | |
| | | L3 ↓ | | | | | |
| | | L1 ↑ | | | | | |
| | | L3 ↑ | | | | | |

Pt: 

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